B13A-0549: Constraining daily-to-annual carbon budgets in a brackish tidal marsh in the San Francisco Bay Delta: Insights on methane and carbon dioxide fluxes from eddy covariance measurements

Sara Knox[2*], Frank E. Anderson[1*], Brian Bergamaschi[1], Lisamarie Windham-Myers[2], John Saraceno[1]

INTRODUCTION

Carbon (C) cycling in coastal wetlands is difficult to measure and model due to extremely dynamic atmospheric (vertical) and hydrologic (lateral) fluxes, as well as sensitivities to dynamic land- and ocean-based drivers. To date, few studies have begun continuous measurements of vertical and/or lateral C exchanges in these systems and as such our understanding of the key drivers of carbon cycling in coastal wetlands including inundation, soil and air temperatures, radiation, and salinity remain poorly understood. Increasing the number of direct simultaneous measurements of vertical and lateral C fluxes is a critical first step to developing a better understanding of the drivers and sensitivities of C sequestration and greenhouse gas (GHG) mitigation potential of coastal wetlands. Here we present concomitant continuous measurements of vertical and lateral C fluxes from a brackish tidal marsh in Northern California, and investigate the biophysical drivers of whole ecosystem CO_2 flux for improved understanding of the controls and timing of surface-atmosphere flux dynamics.

METHODS

STUDY SITE

Rush Ranch (RR) is located in the San Francisco Bay National Estuarine Research Reserve (NERR) in Suisun Bay, CA, the most extensive marsh complex of the San Francisco Bay Delta, which itself is the largest estuary in the western U.S. The site is dominated by sedges (*Schoenoplectus* and *Typha* species), although it is increasingly influenced by an invasive perennial forb (*Lepidium latifolium L.*). RR is classified as a high marsh, which the National Wetland Inventory estimates represents >58% of estuarine wetlands.

VERTICAL & LATERAL FLUX MEASUREMENTS

Net ecosystem carbon dioxide (F_{CO2}) and methane (F_{CH4}) exchange was measured using the eddy covariance technique, with measurements beginning in March 2014. In the summer of 2016, we installed instrumentation to test the quantification of the lateral flux of carbon (F_L) at First Mallard Slough, southwest of the flux tower. The equipment installed includes a YSI water quality meter and C-sense pCO_2 probe.

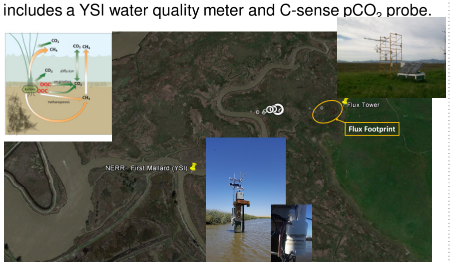
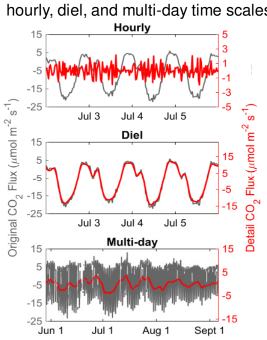


Figure 1. Vertical and lateral flux measurements at the site.

WAVELET DECOMPOSION & INFORMATION THEORY

We used a combination of wavelet analysis and information theory to analyze interactions between whole-ecosystem F_{CO2} and biophysical drivers. Time scales of variability in fluxes and environmental variables were decomposed using the maximal-overlap discrete wavelet transform. Figure 2 illustrates the wavelet detail reconstruction for hourly, diel, and multi-day time scales.



Then the relative mutual information (I^R) between F_{CO2} and biophysical drivers was computed within each time scale over a range of time lags (τ) (Sturtevant et al., 2015). I^R represents a normalized measure of statistical dependence of Y on X, with higher values indicating greater dependence. The power of mutual information lies in the lack of parametric assumptions about the relationship between X and Y and thus is able to identify linear and nonlinear interactions alike.

Figure 2. Example F_{CO2} variation isolated with wavelet decomposition at the hourly, diel, multiday, and seasonal time scales. Gray lines and points are original half-hourly measurements. The red line indicates the wavelet detail reconstruction.

RESULTS

ATMOSPHERIC FLUXES & ENVIRONMENTAL CONDITIONS

F_{CO2} showed significant interannual variability, with low net CO_2 uptake in the first year of the study (67 g C m^{-2} yr^{-1}; March 2014 – March 2015), and considerably higher uptake the following year (295 g C m^{-2} yr^{-1}; March 2015 – March 2016). Conversely, annual F_{CH4} was similar between years (1.2 & 1.3 g C m^{-2} yr^{-1} in the first and second year, respectively). With respect to the net atmospheric GHG budget, (assuming a sustained GWP of 45), the wetland was a net GHG sink of 172 g CO_2eq m^{-2} yr^{-1} in 2014 – 2015, and a sink of 1004 g CO_2eq m^{-2} yr^{-1} in 2015 – 2016.

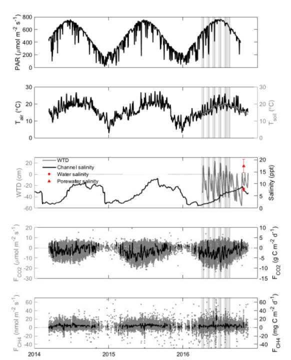


Figure 3. Daily average or half-hourly environmental conditions and greenhouse gas fluxes at the site from March 2014 to November 2016. Gray vertical bars represent spring and neap tide analysis.

INTERACTIONS BETWEEN F_{CO2} & BIOPHYSICAL VARIABLES

Figure 4 shows how the relative mutual information (I^R) between F_{CO2} and biophysical variables varied from hourly to multi-day time scales. This figure indicates the most significant eco-atmosphere interactions at each time scale, which is indicated by the length of the bars, and whether a lead or lag was involved in the process, as indicated by colored extensions to the bars.

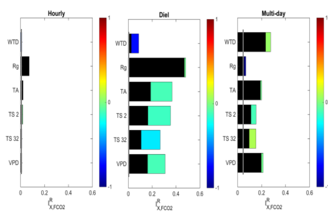


Figure 4. Relative mutual information ($I^R_{X,FCO2}$) between F_{CO2} & biophysical variables (X = each variable on the y axis) from hourly to multi-day time scales. Biophysical variables include, water table depth (WTD), incoming global radiation (Rg), air temperature (TA), soil temperature at 2 cm (TS 2), soil temperature at 32cm (TS 32), and vapor pressure deficit (VPD).

Multi-day variation in F_{CO2} was most strongly linked to water table depth (WTD). Examination of the detail reconstruction at the multi-day scale showed that net CO_2 uptake increased nearly synchronously with increasing water levels (i.e. spring tides) (Figure 5a).

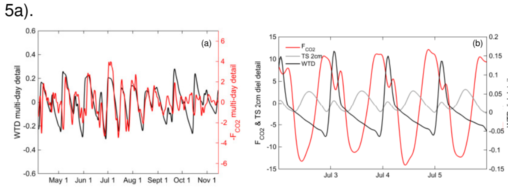


Figure 5. (a) Multi-day and (b) diel wavelet detail reconstructions of F_{CO2}, WTD, and soil temperature at 2cm depth (TS 2cm).

At the hourly and diel scales, F_{CO2} was dominantly and largely synchronously coupled to radiation. However, as observed at the seasonal scale, there was also a significant coupling between F_{CO2} and WTD, with nighttime high tides resulting in a drop in respiration, despite incoming warmer waters causing an increase in soil temperature (Figure 5b).

INFLUENCE OF TIDES ON F_{CO2}, GPP, and ER

Large variations in environmental conditions made it difficult to assess the influence of tides on F_{CO2}, photosynthesis (GPP), and respiration (ER) (Figure 6). However, with respect to ER, nighttime temperatures in April and June were not significantly different between neap & spring tides, while ER did differ significantly; ER was 25% (April) to 33% (June) lower under higher water levels, indicating the importance of tides in modulating F_{CO2}.

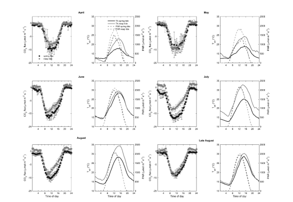


Figure 6. Diel average patterns of F_{CO2}, TA, & PAR during spring and neap tides.

INFLUENCE OF TIDES ON F_{CO2}, GPP, and ER (CONT.)

We partitioned NEE into ER & GPP using the equation of Lasslop et al. (2010), including the VPD limitation of GPP:

$$NEE = \frac{\alpha\beta R_g}{\alpha R_g + \beta} + r_b \exp\left(E_0\left(\frac{1}{T_{ref} - T_0} - \frac{1}{T_{air} - T_0}\right)\right)$$

GPP and R_{eco} during spring tides were modeled using parameters estimated during both spring and neap tides, thus allowing us to investigate the influence of flooding by comparing the differences in model results.

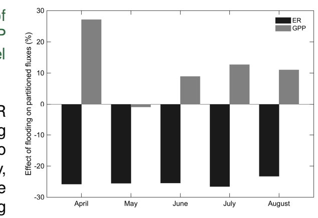


Figure 7. Influence of tides on ER & GPP based on model results.

Across all month, ER was ~ 25% lower during spring tides relative to neap tides. Conversely, with the exception of the month of May, flooding resulted in an increase in photosynthesis, with photosynthesis enhanced by 9 to 27%.

LATERAL FLUXES

Our approach for estimating lateral fluxes uses flow rates and stage heights along with water quality variables from First Mallard Slough:

$$F_L \cong \frac{Q \times (DIC[pH, Sal, pCO_2] + DOC[fDOM])}{Watershed\ Surface\ Area}$$

where *Q* is tidal discharge rates, *DIC is* dissolved inorganic carbon (modelled using pH, salinity and dissolved CO_2) and DOC which is dissolved organic carbon (modelled from direct measurements of Fluorescent Dissolved Organic Matter (fDOM)). Preliminary results indicate that understanding the dynamic tidal environment is key in accurately quantifying the lateral flux term.

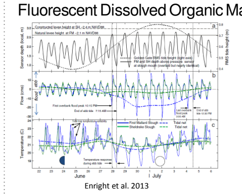


Figure 8. Overbanking of flood tides influence both areal extent of watershed, but also modify temperature.

CONCLUSIONS & FUTURE DIRECTIONS

- Our results show that episodic flooding significantly influenced F_{CO2} at the marsh.
- While there are several potential mechanisms that can contribute to the suppression of respiration following flooding, our results suggest that tidal effects may largely be due to the suppression of CO_2 efflux from the soil as the water creates a physical barrier against gas diffusion. If this is the case, it is important to consider lateral fluxes as flooding may also coincide with increased DIC loss from the marsh.
- Further research on lateral C transport is key to investigating the influence of tides on the role of coastal wetlands as C sinks or sources.

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[1]U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA
[2]U.S. Geological Survey, Menlo Park, CA
[*]Shared First Authorship

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